Miniature Absolute Scalar Magnetometer for Resource-Constrained Solar System Body Exploration

Completed Technology Project (2017 - 2019)

Project Introduction

The magnetic field is a fundamental physical quantity, and its accurate measurement with absolute stability to better than 1 nT is required for many future solar system exploration missions. Future missions requiring this capability include the Europa Lander, which could resolve induction signals to characterize Europa's sub-surface ocean; the Uranus Orbiter and Probe, which seeks to characterize Uranus' unique offset multi-pole magnetic field; an Enceladus Orbiter; and the Lunar Geophysical Network. All of these missions require measurement of small-amplitude magnetic signals with excellent long-term stability. Europa induced magnetic fields are a few nano-Teslas in amplitude and are generated by exposure to periodic magnetic field variations resulting from the rotation of the Jovian tilted magnetic field about the planetary spin axis at a period of ~11 h and from the moon traversing the magnetic environment of its host planet in an eccentric orbit at a period of ~85 h. Magnetic sounding is already an integral investigation of the Europa Multiple Flyby Mission, and it is ideally complemented by lander observations because the induction response is sensitive to altitude so that the induction science return is greatly enhanced by combining the high-altitude flyby observations with those from the surface. Fluxgate magnetometers alone cannot deliver the required performance because their calibration can drift so that long-term stability is not guaranteed. The proven solution is to partner the high-heritage fluxgate instruments with an absolute reference magnetometer, which serves as a calibration source. The fact is, however, that the mass and power of such instrument combination and of most atomic magnetometers alone exceed the capabilities of many planetary missions, especially those with a lander element. To solve the resource problem, The Johns Hopkins University Applied Physics Laboratory and the National Institute of Standards and Technology have developed a novel miniature absolute scalar rubidium (Rb) magnetometer within the Planetary Instrument Concepts for the Advancement of Solar System Observations (PICASSO) program. The use of recently developed micro-fabricated Rb vapor cells illuminated with a low-power vertical-cavity surface-emitting laser allows for significant reductions of instrument size and power, while retaining the ability to provide an absolute reference. The present prototype has a total mass of 210 g (sensors and electronics), uses <1 W of power, and operates in both Mx and Mz mode, allowing high measurement speed and absolute accuracy. A sensitivity of 15 $pT/\sqrt{Hz}$ at 1 Hz, or 0.1 nT rms, at a sampling time of 100 ms has been demonstrated in a laboratory environment (TRL 4). The objective of the proposed work is to leverage our advances toward a low-resource absolute magnetometer within the PICASSO program and develop and demonstrate in a relevant environment a prototype vector instrument for resource-constrained solar system body exploration including ocean worlds and in particular the Europa lander. The development consists of: (a) testing key sensor components for the Europa radiation environment and incorporating mitigation steps in the sensor design; (b) implementing vector measurement capability; (c) designing and fabricating a low thermal resource magnetic field sensor; (d)

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Organizational Responsibility

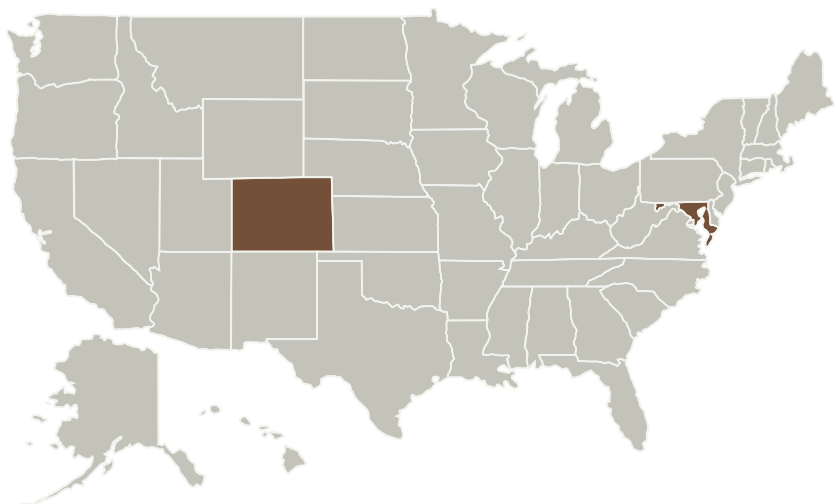
Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Maturation of Instruments for Solar System Exploration implementing electronics in flight-equivalent packaging; (e) quantifying instrument performance characteristics; and (f) demonstrating the prototype in relevant thermal and vibration environments. The result will be a TRL-6 qualified instrument with well-defined resource requirements and performance characteristics. The proposed effort will substantially improve instrument measurement capabilities for planetary science missions in support of the Science Mission Directorate's Planetary Science Division, which is the ultimate goal of the Maturation of Instruments for Solar System Exploration (MatISSE) program.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Johns Hopkins University	Supporting Organization	Academia	Baltimore, Maryland

Primary U.S. Work Locations	
Colorado	Maryland

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Haris Riris

Principal Investigator:

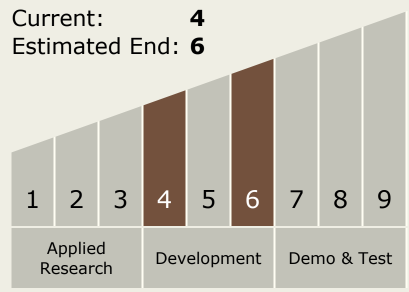
Haje Korth

Co-Investigators:

John E Kitching
Brian J Anderson
Felicia Hastings

Technology Maturity (TRL)

Start: **4**
Current: **4**
Estimated End: **6**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  └ TX08.3 In-Situ Instruments and Sensors
    └ TX08.3.1 Field and Particle Detectors

Target Destination

Others Inside the Solar System